HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII
Under the supervision of the
UNITED STATES DEPARTMENT OF AGRICULTURE

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION

1929

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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU

[Under the supervision of the Office of Experiment Stations, United States Department of Agriculture]

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SUMMARY OF INVESTIGATIONS

By J. M. Westgate, *Director*

During the fiscal year 1929 the station devoted its energies largely to the solution of problems vitally affecting the diversified agricultural industries of the islands. The agricultural extension activities of the station were transferred to the University of Hawaii because the various Federal appropriations for this work had been made available to the Territory of Hawaii through the University of Hawaii. The actual transfer of workers and activities was brought about throughout the year as rapidly as possible. With the inclusion of the Territory of Hawaii in the benefits of the various Federal appropriations under the Hatch, Adams, and Purnell Acts, plans were made by the United States Department of Agriculture and the University of Hawaii for the execution of a coordinated set of projects under a single director for the enlarged experiment station. These projects are to be financed from funds (1) appropriated direct to the Hawaii station through the United States Department of Agriculture, (2) accruing to the University of Hawaii through the application of the Hatch, Adams, and Purnell Acts, and (3) appropriated by the Territory of Hawaii to the University of Hawaii for the Hawaii station. It is felt that this arrangement,

effective July 1, 1929, marks a distinct step forward in the development of agricultural investigational activities in Hawaii.

In the horticultural division approximately 28,000 plants or packages of seed of improved varieties of fruits, nuts, and vegetables were distributed to local growers for trial. Sixty-eight different species of economic plants were introduced from the mainland and from foreign countries during the year, several varieties of each kind being obtained in a number of instances. Successful budding and grafting experiments were continued with coffee, the Macadamia nut, litchi, annonas, carambola, and *Eugenia* spp. Grafting and budding of these species are attended with much difficulty unless special precautions are taken. Considerable work was done looking toward the establishment of improved methods of propagating small plants which come true to seed. Certain kinds of plants that are usually propagated by cuttings were made the subject of special study. Studies of the varieties and pollination habits of the avocado and the papaya were continued. Much attention was given to the development of certain coffee experiments, and in this connection a number of the different species were assembled for use in hybridization work and in determining the relative merits of the different species as rootstock material. One of the most interesting investigations of the year was that undertaken with the large native raspberry, locally known as the akala (*Rubus hawaiiensis* and *R. macræi*). Under favorable conditions the individual fruits attain a maximum diameter of 2 inches. Numerous seedlings are now being tested at various elevations. The Macadamia nut tree is receiving increasing attention from commercial growers, and every effort is being made to solve the various problems in connection with its commercial development.

Work in the chemical division was again concentrated on various problems dealing with the edible canna starch industry. A brief survey of the coffee soils in the Kona district, Hawaii, was made. A study was made of the soil colloids in representative soil samples obtained from various locations throughout the Hawaiian Islands. A preliminary survey was also made to determine the regions best adapted to the commercial production of edible canna. Analyses of 28 kinds of range grasses and forage crops were completed. Chemical studies of Macadamia nuts from various seedling trees indicate the need of standardizing the crop for commercial use. The fruit was found to vary widely in oil and sugar content. A method based on the specific gravity of the nuts was worked out permitting the separation of the nuts from each tree into different grades of maturity.

Agronomic work centered largely on field crops which give promise of aiding the development of diversified agriculture in the islands. Seven different varieties of edible canna were grown in comparison with other root crops, including cassava, ginger, taro, kudzu, and sweetpotatoes. One hundred and thirty varieties of sweetpotatoes were under test. To determine their value as forage crops, Napier grass, Merker grass, Mexican grass, and Kikuyu grass were tested during the year. Some attention was given to a study of the best methods of utilizing rice lands that are being abandoned because of the depredations made upon the crop by the rice borer. Other activities included corn breeding, attempts to develop a solid-headed

strain of lettuce for the lower altitudes, tests with green-manuring crops, a study of the effect of chemicals on weeds, and investigations of the cultural requirements of certain oriental vegetables. The agronomist continued to assist local poultrymen with their poultry problems and helped to stage the Maui and Kauai poultry shows in October and again in December, 1928.

At the Haleakala substation attention was again given to the solution of various agricultural problems of interest to the island of Maui. Some 188 varieties of 60 different kinds of crops were tested. Distribution of small lots of planting material of improved strains under test was an important part of the work of the year. Efforts are being continued to develop strains of pigeon peas that will mature at the higher elevations throughout the islands. Studies were made to determine the effect of different green-manure and cover crops and of different fertilizers on yield of pineapples. Partly as a result of the work of the substation, the Maui pineapple plantings have been extended to areas several hundred feet higher than it was previously thought possible to grow the crop. In an effort to enlarge the area in pineapples, cooperative experiments were undertaken at an elevation of about 3,300 feet near Olinda on the slopes of Haleakala. Experiments were continued to determine the cultural requirements of edible canna as a promising source of commercial starch.

During the year the extension activities of the station, including the 4–H club work, were gradually transferred to the University of Hawaii, which now receives the benefit of the Smith-Lever and other Federal appropriations for agricultural extension work.

REPORT OF THE HORTICULTURAL DIVISION

By W. T. Pope

TROPICAL FRUITS

INTRODUCTIONS

The introduction of tropical fruit trees was not large in number of species as compared with that made in previous years, but some of the additions are valuable, and a number of them are new to Hawaii. Of 68 different species introduced, the following are listed.

The marang (*Artocarpus odoratissimus*), a seeded form of breadfruit from the Philippines, said to be a very large ornamental and fruit-producing tree of considerable value; the lanzon (*Lansium domesticum*), a small fruit tree of considerable importance in the Philippines and parts of tropical Asia; the Macadamia nut (*Macadamia ternifolia*), a thin-shelled variety from Australia; the rednut (*Hicksbeachia pinnatifolia*), a handsome ornamental tree which produces edible nuts; Tinospora (*T. crispa*), a medicinal vine from the Philippines; the butternut (*Juglans cinerea*), a common native of the Southern States; the kawa (*Nephelium pinnatum*), a fruit tree which was introduced from Tahiti; the akala (*Rubus hawaiiensis*) from Mount Puu Hualalai, elevation 5,500 feet, on the island of Hawaii; the Vangueria (*V. edulis*), which was introduced from the island of Tahiti; the chestnut (*Castanea vesca*) from the eastern part of the United States; the black walnut (*Juglans nigra*) from the central part of the United States; the Tahitian coconut (*Cocos*

nucifera) from the Society Islands; coffee, including 21 seedlings of *Coffea robusta*, 50 seedlings of *C. arabica*, and 1 seedling of *C. excelsa*, from Tanganyika, Africa, through the United States Department of Agriculture; seeds of the Madame Russell papaya (*Carica papaya*) from the island of Haiti, West Indies, through the United States Department of Agriculture; seeds of an unusually fine-fruited tamarind (*Tamarindus indica*) tree from the Philippines; the varieties of raspberry (*Rubus* sp.) Cuthbert, Marlboro, Latham, Ranere (*St. Regis*), Columbia, Gregg, Cumberland, and Salmonberry from Sumner, Wash., 25 Cumberland raspberry plants from Wondervine farm, Ohio, 25 Cuthbert raspberry plants from the Western Washington experiment station, and 4 Kansas raspberry plants from the State experiment station, Manhattan, Kans.; the pili nut (*Canarium polyphyllum*) from New Guinea; the rukam (*Flacourtia rukam*) from the Society Islands; tomato (*Lycopersicum esculentum*) seed of the variety Bountiful from Germany, through R. Behrns; and breadfruit (*Artocarpus incisa*) root cuttings of the varieties Hamoa, Rare, Paere, and Maire from the Society Islands.

DISTRIBUTIONS

Approximately 28,000 plants were distributed to cooperative experimenters during the year. Many species of unusual value, either improved or new to the island, were distributed as a means of getting them into cultivation. The distributions included mainly avocado seedlings and grafted trees, banana propagating material of different varieties, carambola seedlings of both sweet and sour fruited varieties, carissa, cashew, cherimoya, coffee, date seedlings, fig cuttings, *Passiflora* spp., Isabella grapevines, several kinds of guava, grafted lemon trees, seedling lime trees, seedling litchi, egg fruit, mabolo, mango grafts and seedlings, mountain-apple seedlings, mulberry cuttings, Macadamia-nut seedlings, grafted orange trees and Hawaiian seedling oranges, papaya seedlings, Surinam-cherry, Brazil cherry, pomegranate plants, grafted grapefruit, grafted shaddock. rose-apple trees, roselle plants, sapodilla plants, soursop plants, star-apple seedlings, tomato plants (station hybrid), and the tree-tomato.

KINDS UNDER OBSERVATION

A study was made of a number of fruit plants both at the central station in Honolulu and with cooperative experimenters throughout the Territory. An annotated list of the plants under observation is given herewith.

Akala (*Rubus hawaiiensis*).—Seedlings of the akala are under cultivation for the first time at the central station. The seeds germinated and the young seedlings are growing very well. Some of them have been placed at the Tantalus substation (1,000 feet elevation) for further growth. Their early growth there is satisfactory.

Avocado (*Persea americana*).—During the year several thousand avocado seedlings were raised from both West Indian and Guatemalan seeds. Part of these have been used for grafting experiments. Some grafting work was also done on seedlings developed the previous year.

Banana (*Musa sapientum*).—Banana requirements have been rather thoroughly worked out in previous years, but planting material is still under cultivation and observation at the station.

FIGURE 1.—Fruit cluster of bignay (*Antidesma bunius*). Tree fruited at the station in 1928

Barbados cherry (*Malpighia glabra*).—The Barbados cherry has never been found to be of importance in the Territory, but it is now on trial at the station.

Bignay (*Antidesma bunius*).—The bignay was introduced into Hawaii by the station some years ago. The trees have fruited heavily at the Tantalus substation.

Brazil cherry (*Eugenia brasiliensis*).—The Brazil cherry grows well in many parts of the Territory at the lower elevations. It requires a deep, moist soil.

Carambola (*Averrhoa carambola*).—Trees of both the sweet and sour varieties of carambola have been under cultivation at the station and fruited freely during the year. Seedlings have also been grown in the nursery.

Carissa (*C. arduina*).—Carissa plants of considerable size are growing at various places in the station grounds. They thrive in a variety of soils and fruit freely, particularly at the lower elevations.

Carob (*Ceratonia siliqua*).—Carob trees have been tested at the station for some years but they grow slowly.

Cherimoya (*Annona cherimola*).—The cherimoya is under cultivation at the station but the elevation is too low for rapid growth and prolific fruiting habits. The cherimoya makes its best growth at elevations of 1,000 to 2,500 feet where the rainfall is moderate.

Citron (*Citrus medica*).—Citron grows to some extent in the Territory. Two trees are on trial in the station citrus orchard.

Cocoa (*Theobroma cacao*).—Cocoa trees are being tried in the station orchard, but they are too exacting in their requirements for station conditions. They require a warm, moist soil and climate.

Coffee (*Coffea* sp.).—Coffee has been on trial at the Tantalus substation for many years. During the year seedlings of several different species were under development at the central station nursery, and a large number of them were transplanted to the Tantalus substation.

Bullock's-heart (*Annona reticulata*).—One tree of bullock's-heart is growing in the station orchard and is fruiting rather freely.

Date (*Phœnix dactylifera*).—The date tree does well in many parts of the Territory, especially in the hot, dry localities where irrigation water can be furnished. Date seedlings of hybrids, introduced the previous year, were grown at the central station. A portion of the supply was distributed to cooperative experimenters.

Fig (*Ficus carica*).—Fig trees of a number of varieties are on trial at the central station and at the Tantalus substation, and cuttings are occasionally rooted to permit distributing these varieties for general culture in various parts of the Territory.

Granadilla (*Passiflora quadrangularis*).—The granadilla vine is on trial at the Tantalus substation. The plants furnish propagating material for distribution.

Grapes (*Vitis* sp.).—The grape experiments which have been carried on for the past several years were concluded. The Isabella is the only variety that is resistant to soil conditions. Successful grape growing is somewhat hindered by the Japanese beetle which feeds on the foliage in some localities. It has been controlled to some extent by spraying the plants with water at the approach of darkness. Grape growing is very successful in localities where evening showers are frequent.

Guava (*Guava* spp.).—Several species and varieties of guava are grown throughout the Territory and have been under test at the experiment station.

Java plum (*Eugenia jambolana*).—The Java plum has received very little attention, although many variations of it are grown

throughout the Territory. Several trees have been fruiting under observation at the Hawaii station.

Jujube (*Ziziphus jujuba*).—Some species of jujube have been cultivated in Hawaii for many years and trees of considerable size can be found in Honolulu. New varieties introduced by the station have not been successfully grown. During the year some of the plants were distributed for cultivation at various elevations.

Kumquat (*Citrus japonica*).—The kumquat is successfully grown along with other kinds of citrus in the Territory. None is under test at the station.

Lanzon (*Lansium domesticum*).—Small seedlings of the lanzon tree of the Philippines are now being developed at the central station.

Lemon (*Citrus limonia*).—The station has a number of varieties of lemon trees under cultivation, and they fruit abundantly but are seriously attacked by gum diseases. For many years they have been used as a source of graft-wood material for use in carrying on experimental work.

Limes (*Citrus aurantifolia*).—A number of varieties of limes are growing in various parts of the Territory. Trees of most of these varieties have been under test at the station. Perhaps the favorite is the Kusaie, which does unusually well at the station, but is attacked to some extent by the fruit fly.

Litchi (*Litchi chinensis*).—A number of varieties of litchi are under test at the station. Seedlings have been raised for grafting experiments. The litchi does unusually well at 1,000 feet elevation in the Kona district, Hawaii. It is exacting in its requirements, however, and for that reason its culture has not been extended to most localities.

Loquat (*Eriobotrya japonica*).—The loquat is easily grown in many parts of the Territory and has been under test and observation at the Tantalus substation for many years. The fruit is a very favorable host for the fruit fly and has received little attention in recent years for this reason.

Lucuma (*Lucuma obovata.*)—The lucuma, or egg fruit, is very successfully grown locally, but has not as yet met with much favor.

Longan (*Euphoria longana*).—The longan is grown to some extent in many parts of the Territory. In several localities the trees fruit abundantly. Longan trees have been grown on the station grounds for years but have never come into fruit.

Mabolo (*Diospyros discolor*).—The mabolo tree was recently introduced into Hawaii from the Philippines. The young seedlings have been distributed to interested growers and are reported to be in fruit. Specimen trees in the station orchard are blooming this year. (Fig. 2.)

Mamey (*Mammea americana*).—The mamey apple tree attains considerable size and grows in many parts of the Hawaiian Islands, particularly at the lower elevations. It fruits freely, but the fruit is not generally a favorite. A single tree is growing in the station orchard.

Mango (*Mangifera indica*).—The mango, which is one of the leading fruit trees of Hawaii, has been under experiment at the station for many years. A small orchard of the trees is being maintained

to permit a study of their culture and as a source of grafting material.

Mangosteen (*Garcinia mangostana*).—The mangosteen is now grown in several places in the Territory but is too exacting in its requirements to suit every locality. Seedlings introduced by the station usually failed to withstand local conditions.

Monstera or ceriman (*Monstera deliciosa*).—The ornamental monstera is under observation at the station. It is again fruiting freely, but as yet the fruit has met with little favor.

Mountain apple (*Eugenia malaccensis*).—A study of the mountain apple indicates that it will grow in a great variety of climates and soils. The fruit is valuable, and the trees are beginning to be generally grown in the home gardens. The mountain apple has been

FIGURE 2.—The mabolo (*Diospyros discolor*) which fruited in Hawaii in 1928 for the first time

under cultivation for years at the Tantalus substation, and each year many seedlings have been grown in the nursery for distribution.

Mulberry (*Morus nigra*).—A number of mulberry trees have been experimented with and have proved to be a source of propagating material. Many rooted cuttings are distributed each year.

Macadamia nut (*Macadamia ternifolia*).—The Macadamia nut tree is becoming popular and received considerable attention during the year. Several trees at the Tantalus substation have been the source of propagating material. During the year grafting experiments were in progress.

Orange (*Citrus sinensis*).—The varieties of orange Washington Navel, Ruby, Valencia, and Hawaiian seedlings, are all under test in the station orchard. The orange can be grown satisfactorily in parts of Hawaii where it can have considerable warmth and an abundance of soil moisture.

Papaya (*Carica papaya*).—Papaya investigations were completed during the year and the results prepared for publication in bulletin form.

Peach (*Amygdalus persica*).—Several peach trees are growing in the station orchard but have not as yet come into bearing. The peach tree bears freely in different parts of the islands, but the fruit is seriously attacked by the fruit fly.

Pejibaye (*Guilielma utilis*).—The pejibaye palm, which is a rather recent introduction, is now growing at the station. A number of the seedlings have been distributed to interested growers living in localities that are believed to be similar to those native to the plant.

Persimmon (*Diospyros* spp.).—Both the Asiatic persimmon (*D. kaki*) and the black persimmon (*D. ebenaster*) are grown in a few localities in Hawaii. The latter is now growing at the station.

Poha (*Physalis peruviana*).—The poha grows in many of the moist localities at elevations between 1,000 and 4,000 feet.

Pomegranate (*Punica granatum*).—The pomegranate grows to perfection in some parts of the Territory. Several varieties have been under test at the station for several years, but the fruit is not considered to be of much value.

Pomelo (*Citrus decumana*).—Good grapefruit and shaddock are sometimes produced both in the station orchard and by growers throughout the Territory.

Roselle (*Hibiscus sabdariffa*).—The roselle, as a jelly plant, is little grown in Hawaii. The experiments which have been in progress for some time at the station have been discontinued.

Sapodilla (*Achras sapota*).—Two sapodilla trees are to be found growing at the station. The sapodilla fruits abundantly in many parts of Hawaii, but the fruit is rather insipid and considered to be of little value.

White-sapote (*Casimiroa edulis*).—One tree of the white-sapote occasionally fruits at the station. Its fruit is of little value. However, there are seedling trees of white-sapote in the Territory that produce a more highly flavored fruit.

Seagrape (*Coccoloba uvifera*).—The seagrape grows at the station, but the fruit is of little value.

Soursop (*Annona muricata*).—The soursop grows well at the lower elevations and some of the seedling trees produce fruit of very desirable flavor.

Star-apple (*Chrysophyllum cainito*).—Considerable attention has been given to the star-apple and the fruit has been favorably received by some.

Strawberry (*Fragaria chiloensis*).—Strawberries have been under observation at the station. They do not do well at the lower elevations. At an elevation of 1,200 feet the plants produce abundant fruit of good quality.

Tahitian chestnut (*Inocarpus edulis*).—A few Tahitian-chestnut trees grow in the Hawaiian Islands. A number of small plantings are being developed at the station.

Tomato (*Lycopersicum esculentum*).—Experiments with the tomato have been discontinued with the exception of the growing of the station hybrid, the result of a cross between the well-known Earliana and a wild tomato. This hybrid is being maintained at

the station, and some effort given to its improvement by seed selection.

Tree-tomato (*Cyphomandra betacea*).—The tree-tomato is worthy of more consideration in this Territory than it now receives. It does well in some localities and the fruit sells readily.

Vanilla (*V. planifolia*).—Specimen plants of vanilla are being grown in the slat-propagating house at the station. Vanilla production has been a small industry in Hawaii for a number of years.

Waterlemon (*Passiflora laurifolia*).—The waterlemon, although an introduced plant, now grows wild in the woods in some parts of the islands. It is frequently under test at the station, and plants have been distributed to interested growers.

Wi-fruit (*Spondias dulcis*).—The wi-fruit has been under cultivation in the Hawaiian Islands for many years. One wi-fruit tree is growing in the station orchard.

METHODS OF PROPAGATION INVESTIGATIONS

Many kinds of fruit trees which are grown in limited areas in Hawaii might be developed commercially. Perhaps the most vital horticultural factor governing commercial orchard production is the determination of suitable propagation methods. For several reasons fruit-tree propagation is unusually complicated. Most of the fruit trees now growing in the Hawaiian Islands have fixed characters which are peculiar to the parts of the world whence they came. The seeds of some trees are adapted for germination under very moist conditions, whereas others require dry conditions. Certain nuts and other kinds of seed germinate very slowly, having been adapted to withstand the long, cold winters of the Temperate Zone. In vegetative propagation by means of cuttings, budding, grafting, and the like, the requirements vary considerably.

Soil mediums for seed.—Coral sand, volcanic sand, and various kinds of composts were used as soil mediums for seed propagation at the station. Coral sand consists of the broken coral rock of the reef. The particles vary in size and are more or less smooth as the result of action by the sea. The sand particles may be screened to meet the requirements of different kinds of plants. Clean coral sand contains very little available plant food. However, this sand when properly moistened has good water-holding capacity and is porous enough to permit a free circulation of air throughout. Under normal Hawaiian temperatures these conditions give warmth, moisture, and oxygen sufficient for the chemical changes taking place in the germination of seeds and the rooting of many kinds of cuttings. Coral sand, being composed largely of lime, is believed to have a preventive effect upon the growth of certain parasitic fungi, commonly known as damping-off disease, which sometimes attacks young seedlings and tender cuttings. For the same reason the surface of the sand when used in propagation is slow in becoming sealed over with a dark green or blackish algae.

Volcanic sand and cinders are commonly called "black sand." Volcanic sand is produced by the action of the sea which breaks comparatively recent lava flows into a smooth-grained sand and builds it above sea level into black sand banks. Cinders are the fragments

of scoriaceous lava which are explosively ejected by volcanoes during an eruption and fall in layerlike deposits over the mountain slopes. The cinder medium is sharper and possibly better adapted for propagation work than are other kinds of mediums. Like the coral sand, the cinder particles vary in size and may require screening before they are used for propagating certain kinds of small and tender seeds. Seeds that have been successfully germinated in flats 12 inches wide by 16 inches long by 3 inches deep include those of the tomato (*Lycopersicum esculentum*), rubus (*Rubus* sp.) carambola (*Averrhoa carambola*), carissa (*Carissa arduina*), guava (*Psidium guajava*), pepper (*Capsicum* sp.), poha (*Physalis peruviana*), roselle (*Hibiscus sabdariffa*), passion fruit (*Passiflora* sp.), algaroba (*Prosopis juliflora*), Philippine berry (*Mutinga calabura*), papaya (*Carica papaya*), and the tree-tomato (*Cyphomandra betacea*). When only a few seeds were to be germinated, shallow flowerpots were used. These containers were placed in an insect-proof glass-covered house where both moisture and temperature could be controlled. Seeds requiring a longer germinating period than those mentioned were placed in a 1-inch layer of coral sand which was overlaid by a 2-inch layer of rich potting soil. The soil contains a greater amount of plant food and stimulates root growth, which then becomes sufficiently established to withstand transplanting to individual containers.

Medium coral sand and medium black sand were separately used for some of the above-mentioned seeds and also for the seeds of the lime (*Citrus aurantifolia*), orange (*Citrus sinensis*), lemon (*C. limonia*), pomelo (*C. decumana*), pomegranate (*Punica granatum*), bignay (*Antidesma bunius*), Brazil cherry (*Eugenia brasiliensis*), carob (*Ceratonia siliqua*), coffee (*Coffea* spp.), date (*Phœnix dactylifera*), mountain apple (*Eugenia malaccensis*), Surinam-cherry (*E. uniflora*), rose apple (*E. jambosa*), sapodilla (*Achras sapota*), black-sapote or black persimmon (*Diospyros ebenaster*), white-sapote (*Casimiroa adulis*), soursop (*Annona muricata*), star-apple (*Chrysophyllum cainito*), and mango (*Mangifera indica*).

Coarse black sand and coarse coral sand were used separately as mediums for the cashew nut (*Anacardium occidentale*), Macadamia nut (*M. ternifolia*), pecan nut (*Carya olivæformis*), black walnut (*Juglans nigra*), butternut (*J. cinerea*), Tahitian chestnut (*Inocarpus edulis*), and Japanese chestnut (*Castanea sativa*).

Special soil mediums were prepared for seeds of unusual requirements. In such soils grated coconut husk, pulverized peat, or sphagnum moss were used to increase the water-holding capacity of the mediums. This is often necessary for very soft seeds of certain fruits from moist, tropical regions. These mediums were used successfully with the lanzon (*Lansium domesticum*), litchi (*L. chinensis*), longan (*Euphoria longana*), and *Eugenia* sp.

Certain kinds of seeds germinate best if they are placed in large propagating benches of coral sand in the open sunlight. At the station these benches were 1 foot deep, 3 feet wide, and 12 feet long. The sand in these benches was sufficiently deep to allow for natural and early extension of the taproot of such seedlings as the avocado and the Macadamia. These attain a length of 6 or 8 inches before forming any side roots. A deep medium also enables the air to cir-

culate freely in the soil. Exposure of the seed bed to the sunlight tends to develop stocky seedlings of a size suitable for early grafting. These seedlings may be successfully transferred to gallon containers in 20 or 30 days after the seed is planted. In transplanting the taproot may be cut back to within 4 or 5 inches to induce a more rapid development of the side roots. After 10 to 15 days in the gallon containers, the avocado plant is of sufficient size for grafting. Macadamia nuts germinate well under these conditions and produce hardier seedlings than when they are grown in soil under partial shade. Deep sand mediums have also been found very satisfactory for rooting cuttings of the Isabella grapevine and other hardwood cuttings.

Vegetative propagation.—Fruit tree vegetative propagation methods, by the rooting of cuttings and by grafting, have been under investigation as a means of rapidly increasing and standardizing certain desirable varieties.

Mature hardwood cuttings were successfully rooted when they were placed in an 8 to 10 inch coral-sand medium in benches in the open sunlight. These cuttings included the fig (*Ficus carica*, three varieties), the Isabella grapevine (*Vitis labrusca*), black mulberry (*Morus nigra*), and granadilla (*Passiflora quadrangularis*). Cuttings of *Carica papaya* were tried in similar deep mediums in the glass-covered house but gave only a small percentage of success. Cuttings taken from the surface roots of seedless varieties of breadfruit (*Artocarpus incisa*) are now rooting. These root cuttings were collected in the Society and Cook Islands, South Pacific Ocean, by G. P. Wilder. The cuttings were about 1½ inches in diameter and 6 inches long and were placed horizontally several inches below the surface of the sand and about 1 inch above a 4-inch layer of fairly rich garden soil. The percentage of success with these cuttings has been relatively large, especially when it is considered that the material was in transit for 36 days, and in some instances was out of the soil for a much longer period.

The grafting of avocado seedling nursery stock varying from 50 days to 14 months from the date of planting the seeds was tried during the year. In the use of the younger material, stock 50 to 60 days old was grafted with medium-tender scions which were taken from the terminals of comparatively new branches of trees of desirable varieties. Cleft or wedge grafting and whip grafting were the two methods used. (Fig. 3, A and B.) In cleft grafting the seedling was cut off squarely about 5 or 6 inches above the ground and the remaining stub was split 1½ or 2 inches to receive the wedge-shaped basal end of the 2½ or 3 inch scions. In whip grafting the stock was cut off at an angle, giving a beveled surface of about 1½ inches in length. In this surface a ¾-inch wedge-shaped tongue was cut to receive a similar tongue made in the beveled surface of the basal end of the scion. One of the most important parts of the entire operation is the selection of scions in a suitable condition of growth. The possibilities of such condition depend greatly upon the season. Although the methods of grafting mentioned were true to name, different methods were employed in binding and covering the unions. Some were bound with only enough raffia to hold them firmly; with others the material was wrapped so as to cover the union completely.

Experiments indicated that the best results were obtained by protecting the bound union, including the entire surface of the scion, with a covering of melted paraffin applied with a brush or as a spray. Wrappers, made from ½-inch strips of white muslin previously dipped in melted grafting wax, and from strips of elastic mending tape, such as is used by tailors, were also used. Another method now giving fairly good results consists in using as binders strips one-half inch wide and 5 inches long cut from old automobile-tire tubes. These strips are stretched tightly about the union with the end tied in what is known as a half hitch. The bandage naturally

FIGURE 3.—Methods of grafting used in standardizing nursery stock at the station: A, Whip grafting; B, cleft or wedge grafting; C, side-tongue grafting; and D, bark grafting

contracts enough to form a tight wrapper. After 10 to 14 days the wrappers are removed.

The various grafting experiments were 35 to 92 per cent successful. The best results in grafting young nursery stock were obtained by using a tight raffia binder and coating the entire surface of the union and scion with a thin layer of melted paraffin. All the unions were satisfactory when both stock and scion were in good condition. The seedlings used in the experiments included the West Indian, Guatemalan, and hybrid kinds. Hybrids which are the result of crosses between Guatemalan and West Indian varieties gave the best results.

The varieties were grafted to the seedlings of the West Indian types Bromley, Seyde, Wilcox No. 3, Isenberg, Preston, Osborn,

Marques, Lewis, Enoi, Lando, Berger, Tantalus, and Trapp; Guatemalan types Macdonald, Nabal, Panchoy, Ishkal, Nimlioh, Kashlan, Kanan, Benik, Mayapan, and Tumin; and hybrids Beardslee, Haley, Ilialu, Lehua, Kinau, and Nutmeg.

A very satisfactory method of side-tongue grafting young mango nursery stock has been employed to increase the number of hybrids. This method of grafting was worked out by the station several years ago and is now generally practiced at the station and by a number of private growers. It is best accomplished with 6 to 8 months old seedlings grown in gallon containers. Such seedlings usually have a stem diameter of about three-eighths inch and a height of about 18 inches. The graft is made in the side of the stem at a distance of 4 or 5 inches above the ground. (Fig. 3, C.) The scion wood should be healthy, clean, plump, firm, and of the same diameter as the stock where it is united. The union is bound firmly with raffia and the whole outer surface of the union, including the tying material, is coated with paraffin. Part of the terminal growth of the stock is then pruned to retard growth at that point. As soon as the leaves put out by the scion have made sufficient growth to function, the rest of the top of the stock is cut off just above the union. The cut surface is then coated with grafting wax. About four to six weeks later the young grafted tree is ready to be set in permanent place in the orchard.

Several other methods of grafting the mango were tried, including cleft or wedge grafting, and bark grafting, but none of them was very successful.

Vegetative methods of propagating nursery stock of citrus varieties were tested during the year. Sour orange and shaddock (*Citrus maxima*) were used as the seedling stock. The latter has proved to be the most vigorous of the several rootstocks tested. Seedlings of several varieties of grapefruit were used and the grafted trees made satisfactory growth but their disease-resistant ability and adaptability to local conditions still remain to be determined. The lime varieties grafted were the Tahiti, Bearss (improved Tahiti), and Kusaie; and the lemon varieties, the Villafranca (rough lemon), and Sweet Lemon, a local variety which was until recently new to the station. Six to eight months old seedlings were grown in gallon containers for bark grafting. In grafting, the seedling is cut off at about 4 inches above the ground and the scion of the desired variety is cut at an angle from one side to the basal end so as to form a beveled surface 1½ inches long. The scion is slipped down inside the bark, which spreads to each longitudinal cut. The union is then firmly bound and the whole union is given a thin coating of melted paraffin. This method is very satisfactory and has in many trials given a large percentage of success. (Fig. 3, D.) The same methods were employed also in grafting the Victoria variety of shaddock, a sweet-shaddock variety, and the Marsh and Foster varieties of grapefruit.

Orange varieties grafted during the year included the Valencia, Navelencia, Hawaiian seedlings, Thomson, Washington Navel, and Golden Buckeye.

Other kinds of trees grafted included the litchi, annonas, Macadamia nut, Eugenias, and carambola. Litchi seedlings from

seed planted in June, 1927, were of good size in January, February, and March, 1929. A number of side-tongue graftings and bark graftings (fig. 3, C and D) were employed successfully. The first mentioned, however, was most successful and resulted in about 25 per cent of successes. It is believed that this method may be eventually worked out as a successful means of locally standardizing the litchi tree for commercial planting. Both longan and litchi stock have been employed in Hawaii in this work, and the lack of disease resistance in the litchi stock has not been found to be an obstacle to the successful culture of this fruit in these islands. (Fig. 4.)

Bullock's-heart (*Annona reticulata*) and cherimoya (*A. cherimola*) were grafted during the year. (Fig. 4, E.) Several trees of each species have been growing in the station orchard for some years.

FIGURE 4.—Fruit trees grafted as a means of standardizing the crops: A, Avocado; B, citrus; C, mango; D, coffee; E, cherimoya; F, Macadamia; and G, litchi

Local conditions are in part suitable for the *A. reticulata*, but the *A. cherimola* does not grow well and does not fruit at the lower elevations. It fruits satisfactorily at altitudes approximating 3,000 feet on the island of Hawaii.

Very little progress was made in the work of grafting Macadamia-nut seedlings because little seedling stock was available for use at the station. However, 800 Macadamia seedlings are now approaching a size suitable for experimental grafting purposes. The seedless water apple (*Eugenia aqua*) was experimented with during the year. The tree is handsome in foliage and flower, and the fruit has possibilities for use as a food. An effort was made to graft it on mountain-apple seedlings, and while the results are encouraging, no great amount of success can as yet be reported. At this writing (June 30, 1929) only one plant appears likely to succeed. The two species, although

related, do not appear to be congenial. Some other related species will be tried as rootstock material. Several improved varieties of *Eugenia malaccensis* indicate the importance of finding a vegetative method for establishing varieties of this useful tree.

AVOCADO AND PAPAYA VARIETIES AND POLLINATION HABITS

Renewed interest in the avocado has resulted in a more thorough study of the varieties of this fruit, and in efforts to establish prolific varieties yielding fruit of high quality having good flavor and being fiber-free. In addition to the studies made by the station, the Hawaiian Avocado Association has appointed a committee to make a study of such varieties as are desirable for general planting. During the year several new hybrids, including the Pratt, were produced and may eventually be propagated. (Fig. 5.)

A small planting of about 30 avocado seedlings at Schofield Barracks at an elevation of about 1,100 feet has attracted considerable attention. These trees are from the seeds of the hybrid Wilder, which is the result of crossing the Macdonald, a Guatemalan type having rough, thick rind, with a West Indian smooth-skinned type. The Wilder has many characters of the mother tree, the Macdonald. The fruit of the Wilder seedlings at Schofield, Oahu, shows some variation, but in general it is much like that of the Wilder. The nature of growth of the seedlings on a high plateau indicates that the environment is suitable, but under the same conditions the growth of West Indian avocados of pure strain is very unsatisfactory.

The matter of pollination seems to be of no concern with the avocado trees at Schofield Barracks, but it is of paramount importance at the Tantalus substation, where many of the trees have failed to set fruit notwithstanding the fact that most of them have blossomed freely every spring for the past five years. In the Tantalus orchard there are 15 introduced Guatemalan varieties, 24 West Indian varieties, and 4 hybrid varieties. Failure of the trees in this orchard to set fruit is no doubt influenced partly by their failure to receive sufficient moisture for the crop. The orchard is located on a steep hillside, and the rain does not percolate through the soil to the root zone unless it falls slowly and steadily. A permanent cover crop of *Commelina nudiflora* has been planted in the orchard in an effort to prevent surface washing.

Much time was devoted to a study of the habits of pollination of the papaya (*Carica papaya*). Pollination and fruit qualities are so closely associated as to make it useless to study the one without also studying the other. During the several years these studies have been in progress the plants have been found to vary widely in character and to produce somewhat irregular fruits. This year, as in other years, it was observed that failure of pollination to take place at some time during the year resulted in some of the plants becoming more or less sterile and that the seedless fruit which was set by some plants without fertilization was usually thin in flesh and poor in flavor. The results of investigations during the year showed that the papaya is subject to mutations and that in pollination the flowers cross freely and display marked evidence in the fruit of the first generation. A small trial orchard of 90 plants set in 1928 has given considerable propagating material for study.

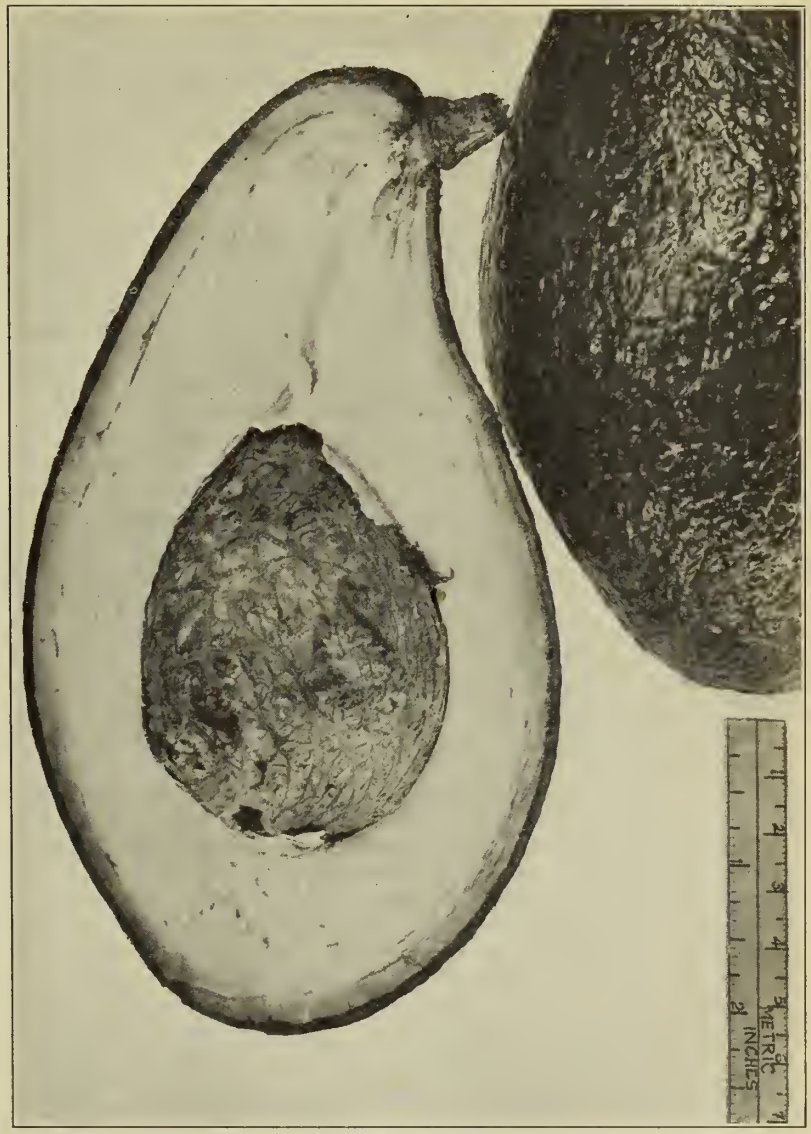

FIGURE 5.—Promising new hybrid avocado, Pratt, which is the result of crossing a Guatemalan and a West Indian variety

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Notes were made of any great variation in stamens as to length, the nature of anthers, and the condition of pollen. Stamens present in pistillate fruit were found to be closely associated with form of fruit. Cultivated papaya plants from carefully selected seeds of dioecious plants tend to have the greatest number of pistillate or fruit-bearing plants.

COFFEE

Renewed interest in coffee growing in Hawaii during the past few years has brought about considerable investigation of the industry. The great variations noted in the yields and grades in the different commercial plantings indicate the importance of using cultural methods for the crop.

Practically the same problems confront the planters in several of the leading coffee-growing countries, and in some places, notably in the Dutch East Indies, the difficulties have been overcome, at least in part, by grafting desirable varieties on resistant rootstocks. The presence of nematodes in Hawaiian soils adds to the problem of developing resistant rootstocks. It is also believed that a study of the relative merits of such species and variations as are adapted to Hawaii is important for improvement of the industry.

Some 779 seedling trees of 3 species and 5 so-called varieties are now under study at the station. Eighty trees of Hawaiian coffee (*Coffea arabica*) and 7 trees of Robusta (*C. robusta*) are growing at the Tantalus substation. The trees of these 2 species are now about 19 years old. Young seedling coffee trees which were set in March at the Tantalus substation included 50 Tanganyika trees (No. 5381)[1], 4 Guatemalan trees (No. 4135), and 60 Hawaiian trees (No. 5383) of the Arabian group (*C. arabica*); 13 Excelsa trees (No. 5382, 1 tree, and No. 3947, 12 trees) of the Liberian group (*C. excelsa*); and 1 Robusta tree (No. 3948) of the robustoid group (*C. robusta*). Remaining in the nursery are 3 Excelsa trees (No. 3947), 1 Guatemalan tree (No. 4135), 1 Java hybrid (No. 3941), and 540 Hawaiian trees (No. 5383).

About 50 of these trees are being used in the grafting experiments and about 140 have been given out for cooperative experiments.

During the early spring about 60 cuttings were put into coral sand, one lot being placed in the glass-covered house and the other in the slat propagation house among larger plants. Most of these failed to make any leaf growth, whereas others produced leaves and soon died. Six are still in the sand but do not appear to be rooting. The leaves produced were developed on the plant food stored in the tissues of the cuttings, there being no roots to support them. About fifty 2-year-old seedlings growing in gallon containers were grafted by the side-tongue grafting method, such as is employed successfully in grafting avocado and mango seedlings. (Fig. 3, C.) The percentage of success was small. The experiment has not yet been continued long enough to give definite results. Former experiments in Hawaii and elsewhere have fully demonstrated the possibilities of grafting nursery stock and old coffee seedlings and of successfully top-working old trees in established coffee orchards.

[1] Number under which the trees were received at the station.

AKALA OR NATIVE RASPBERRY

A greater production of locally grown foodstuffs is needed to satisfy the requirements of the population of the Hawaiian Islands which is increasing at the rate of about 15,000 persons per year. Many of the locally grown horticultural crops seem to have cultural possibilities looking toward the development of small industries which would help to meet these requirements. The successful growth of the native raspberry (*Rubus* sp.), or akala as it is called locally, indicates that it can probably be grown commercially. Explorers, botanists, and others who have visited the islands since their discovery by Europeans in 1778 have been enthusiastic about this wild fruit. William Ellis,[2] who traveled over the island of Hawaii in 1823, observed the growth in six different places of this unusual raspberry and noted that native Hawaiians were growing the plant for its abundant production of luscious fruit.

Two distinct species of akala (*R. hawaiiensis* and *R. macræi*), as well as several related strains have been found growing at comparatively low elevations in the Hawaiian Islands.[3] During the past 100 years the plants have been destroyed to such an extent as now to exist only at the higher elevations in the forest reserves or other protected areas where they produce fruit of large size and fair quality during the summer. The fresh fruit is in strong demand locally, but on account of its perishable nature, the isolated position of the islands, and the high cost of transportation it can not be shipped in the fresh state from the mainland. With the development of an akala industry the fresh fruit could be used locally and the canned fruit for export trade.

During the year the horticulturist spent three days in the Hualalai forest reserve in North Kona, Hawaii, at elevations ranging from 4,500 to 6,000 feet, for the purpose of studying the *Rubus hawaiiensis*. In this forest the akala grows mostly as the underbrush of large trees, but it is sometimes also found in the open clearings. The plants vary from 6 to 10 feet in height. Some of the specimens observed were 15 feet high. The stems are perennial, 1 to 2 inches in diameter, strong, upright, and unarmed after the first or second year's growth. The branches that form the top are spreading and droop under the weight of the fruit which is borne on side spurs. The younger shoots are green or brown, and the entire bark is covered with soft green spines which are one-half to three-fourths inch in length. The leaves are pinnately 3-foliate, sparsely pubescent above and densely tomentose below, and the margins are sharply inciso-lobate and dentate. The plants bloom mainly in March and April and produce the fruit in June and July, but some fruit may be found at almost any time of the year. Two distinct variations of the fruit were found, in one instance the color of the mature fruit being dark purple, and in the other yellow. The dark-purple fruit predominates in the locality visited. The fruit averaged 1 inch in diameter, but

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[2] ELLIS, W. NARRATIVE OF A TOUR THROUGH HAWAII, OR, OWHYHEE; WITH OBSERVATIONS ON THE NATURAL HISTORY OF THE SANDWICH ISLANDS, AND REMARKS ON THE MANNERS, CUSTOMS, TRADITIONS, HISTORY, AND LANGUAGE OF THEIR INHABITANTS. Ed. 2, enl. 480 p. London. 1827.

[3] HILLEBRAND, W. THE FLORA OF THE HAWIIAN ISLANDS: A DESCRIPTION OF THEIR PHANEROGAMS AND VASCULAR CRYPTOGAMS. Annotated and published after author's death by W. F. Hillebrand. P. 116, illus. London, New York [etc.]. 1888.

larger specimens were common. (Figs. 6 and 7.) The fresh fruit is rather tart, but when served with cream and sugar it is delicious. Seeds of the purple type were brought to the central station in Honolulu and germinated, and the seedlings when of suitable size were

FIGURE 6.—Fruit and leaf of akala (*Rubus hawaiiensis*), a native species now under cultivation at the station

transferred to the Tantalus substation where the forest elevation approximates 1,000 feet.

Plants of 11 varieties of *Rubus* spp. have been successfully introduced from the experiment stations in Minnesota, Kansas, Iowa, and

Washington. Most of the plants are now under cultivation at the Tantalus substation.

MACADAMIA NUT

The Macadamia-nut tree has become well established in the Hawaiian Islands. It was first introduced from Australia about 1895

FIGURE 7.—Stem and fruiting branches of akala. Diameter of fruit 1½ to 2 inches

but did not attract much attention until a number of the seedlings came into bearing. The tree is now cultivated in many localities up to an elevation of about 2,500 feet and apparently is not exacting as to soil and moisture requirements. The high quality of the nut and

the general interest manifested in it have been sufficient reasons for making considerable investigations as to its possibilities.

For many years the station has been investigating the culture of this promising nut tree and has distributed large numbers of seedlings to numerous interested growers in the Territory. Owing to the natural variation of the species, it must be propagated by vegetative methods, particularly in places where the nut is to be grown commercially. In an experiment planned to cover a period of 10 years, cultural, varietal, and propagation studies of the Macadamia-nut tree are to be made. Experiments are to be conducted at the central station in Honolulu (150 feet elevation), the Tantalus substation (1,000 feet elevation), and at a proposed substation in Kona (2,000 feet elevation), Hawaii. These localities vary considerably in climate and soil, as well as in altitude.

At present the station has 800 Macadamia seedlings 8 months old as nursery stock, about 40 bearing trees of different ages at the Tantalus substation, and 12 grafted trees from the experiment made last year. Propagating material may also be obtained from cooperative experimenters working in different parts of the Territory.

REPORT OF THE CHEMICAL DIVISION

By J. C. Ripperton and C. Richter

EDIBLE-CANNA INVESTIGATIONS

STARCH PROPERTIES

Details of the method of determining the swelling power of edible-canna starch were worked out. Briefly, the method consists in gelatinizing the starch in a small Erlenmeyer flask by means of hot water delivered from a 100 c. c. pipette. The rolling motion produced in the flask by the hot water keeps the starch granules perfectly scattered while they are being subjected to a temperature which constantly rises until it reaches 80° C. The flask is then kept for 15 minutes at 80°. After 15 minutes the starch solution is poured into a graduated cylinder containing 190 c. c. of distilled water at room temperature, and the contents are thoroughly mixed by inverting the cylinder several times. The solution is then allowed to stand overnight. The starch granules have then settled with a sharp, well-defined boundary surface and a clear supernatant liquid. The volume of the swollen starch granules can be read in cubic centimeters. Since in no part of the entire process is the starch solution stirred or agitated, a large part of the starch exists as unbroken granules in the solution. By determining the swelling power, study is made of the properties of the swollen granules instead of an indefinite mixture of broken and ruptured granules as is usually done.

This method has given some interesting results with respect to the colloidal behavior of a starch solution. Among other things, it has been found that the swollen granule is negatively charged and as such is affected largely by cations. Anions have very little specific effect, but cations cause a reduction in the swell of the granule in proportion to their valence. By plotting the depression of the swell against concentration of cations, a curve is secured which is similar to the adsorption isotherm of a typical colloid.

It has been found that the swelling power of a starch can not be taken as an exact measure of its viscosity. Although for the large proportion of starches a high swelling power is associated with a high viscosity, and vice versa, there are numerous exceptions to the rule. These are being investigated to determine the cause.

In confirmation of the work of others, it was found possible to affect the viscosity and swelling power of a starch greatly by treating the raw starch at room temperatures with various salts and removing the excess salts by subsequent washing with distilled water. Again, the cations were the determining factors. The monovalent ions tended to increase the viscosity and swell, whereas the bivalent ions depressed the values. A number of starches were electrodialyzed and the amount of cations and anions received was determined.

One of the chief objects in beginning the study of the properties of starches was to determine the cause of the large differences in viscosity of edible-canna starches. These differences were found among commercial samples of other starches, but the cause is as yet unknown. The edible canna offers exceptional opportunities in this regard because its starch is susceptible to various factors. For example, the storage of rootstocks even for 48 hours causes a marked reduction in viscosity as compared with that of the starch prepared from the freshly dug rootstocks, and this reduction in viscosity continues with the length of storage. The results thus far indicate that loss of viscosity is an irreversible change, and that except for loss of swell and viscosity, these starches are similar in their reaction to the high viscosity of starches, for example, with respect to electrolyte.

In order to apply the methods developed in this study to better-known starches, comparative tests were made with a series of commercial potato starches. The results thus far indicate a decided similarity between the edible canna and potato starches. This is especially significant since commercial potato starch is at present largely imported and commands the highest price among the industrial starches.

SURVEY OF AREAS ADAPTED TO EDIBLE CANNA

To determine which of the canna-growing areas can be easily developed commercially, a survey was made of Waimea and Hamakua Upland, Hawaii; Kula, Hamakuapoko, and Hana, Maui; and the Kaneohe district, Oahu.

Waimea, Hawaii.—The Waimea district is known to be ideally adapted to the growth of edible canna. The climate is favorable on account of the high altitude, high humidity, and evenly distributed rainfall; the soil is loose, open, and of excellent fertility; and the topography is unusually flat. The yield of canna is very large. Although thousands of acres in this district are adapted to canna, very little of the area could be obtained in fee simple. The Waimea district is now largely devoted to grazing.

Hamakua Upland, Hawaii.—Hamakua Upland extends from Ahualoa to the Kaapahu homesteads. The rainfall of this region is much greater than at Waimea but is more seasonal, and the district is more likely to suffer from drought. The general topography is sufficiently smooth for cultivation, although toward Kaapahu it

is traversed by a number of deep gulches. The soils, particularly those of Ahualoa, are rather low in fertility and heavier in texture than are the soils of Waimea. Test plats of canna at Ahualoa gave fairly good yields. The region is mostly devoted to grazing.

Kula, Maui.—At Kula, test plantings of canna have done exceptionally well. The soil resembles that of Waimea and because of the cool temperature and lack of strong winds the region is desirable for canna growing. The rainfall is seasonal, however, with definite dry seasons. Lack of water would make it necessary to transport the rootstocks to lower levels for manufacture.

Hamakuapoko, Maui.—Hamakuapoko is copiously watered and has excellent soil. Plantings of canna at the Haleakala demonstration farm have done well. At present pineapples occupy nearly all the agricultural area. Should pineapple growing ever be abandoned in this region, edible-canna culture would offer possibilities.

Hana, Maui.—Hana has frequently been mentioned as offering possibilities for canna culture. The climate is undoubtedly desirable, the rainfall being copious and the humidity generally high. The rough topography and steep slope, however, would make it difficult and expensive to bring any large area under cultivation.

Kaneohe, Oahu.—At Kaneohe test plantings of canna have grown well. The rainfall is adequate and fairly well distributed. Kaneohe is close to sea level. The large number of cloudy days are of advantage in canna culture. Although the total area of the district is large, the topography is rather broken and would therefore necessitate planting in numerous small areas. This would appreciably increase the cost of production. Water is plentiful in Kaneohe for manufacturing purposes, and cost of trucking the starch to the Honolulu waterfront would be small.

EDIBLE CANNA IN ROTATION WITH PINEAPPLES

Working in cooperation with a local pineapple company, the station planted four ½-acre plats of edible canna on Oahu. The purpose of the planting was to determine the value of edible canna as a green manure in rotation with pineapples. If the canna proved to be resistant to the root-knot nematode of the pineapple, the top growth of the former might be used as a green manure in pineapple culture, and the rootstocks as a source of commercial starch. The results of the test were conflicting. At Waipio, where the soil was heavily infested with nematodes, the canna roots were appreciably affected, whereas at Pupukea, where there was another heavily infested area, canna showed practically no infestation. It is concluded, therefore, that edible canna should not be planted in a field immediately after a heavily infested pineapple ratoon has been plowed under, and that on soils not badly infested the canna can safely be used.

RANGE-GRASS NOTES

A number of ranches in the different islands were visited to determine the general nature of the range grasses growing thereon, particularly with respect to the introduced grasses. Herbarium specimens of different species were taken and subsequently identified. Samples of 28 grasses were collected and their nutritive constituents

determined. A number of samples of the new growth of the ekoa (*Leucæna glauca*) were also taken for analysis. It has often been contended that the ekoa is equivalent in feeding value to the pigeon pea. Results of analysis show, on a dry basis, that both the young leaves and immature pods have about the same feeding value as the pigeon pea (upper third of plant with seed in pod.)

COMPOSITION OF MACADAMIA NUTS FROM SEEDLINGS

Local plantings of the Macadamia nut are almost entirely seedlings. Nuts from different trees differ greatly in appearance, size, and thickness of shell. To determine whether these differences would also be accompanied by differences in chemical composition, seven samples were collected from individual trees growing in widely different localities. Determination of their nutritive constituents showed that of the two groups formed one was higher in oil and lower in sugars, and the other was lower in oil and higher in sugars. The other constituents were relatively constant. To determine to what extent maturity might account for these differences in composition, samples from a number of trees in the same locality were collected and the nuts in each sample divided into groups, depending on whether the outer hull of the nut was wholly green, part green, or entirely dry at the time the nut fell to the ground. The content of oil and sugars was found to vary within wide limits, depending on maturity. In the immature nuts the oil was low and the sugars were high, whereas the opposite was true in the mature nuts. Variations in composition among the trees tested were small. A method based on the specific gravity of the nut was worked out for use in separating the nuts of each tree into different grades of maturity. The groups of lighter specific gravity represented the immature nuts, and the group of greatest specific gravity represented the fully mature nuts. Only the latter should be used in analyses to compare the composition of nuts from different trees.

SURVEY OF THE SOILS OF THE KONA DISTRICT

A preliminary survey was made of the soils of the Kona district to determine the general nature of the soils, whether distinct types of soil and subsoil could be distinguished, and whether a general soil survey of the district would be feasible. The soils of Kona are relatively young. They are largely residual and are the result of the decomposition of lava flows which are mostly of the "a-a" type. In some places decomposition of the lava is at a more advanced stage than in others, the soil being deep and fine in texture. In general, however, decomposition is in the early stages; the soil is shallow, and the undecomposed lava is often apparent at the surface. It is a striking fact that the coffee trees make thrifty and vigorous growth on what appears to be practically undecomposed lava. The soil profile generally shows no pronounced difference in color or texture even in the deeper soils. Of the possible differences in soil types, there is a fine-textured type which previously was planted with sugarcane. The subsoil is pronouncedly yellow in color and heavy in texture. The most common type is loose in texture and black in color, merging gradually into a subsoil of the same texture

and of a dark-brown color. A possible third type is yellow in color and generally poor in fertility. It is said to be associated with a different type of lava.

Analyses were made of a series of 13 soil samples representing widely different parts of the district, and determination was made of their moisture, color, moisture equivalent, colloids, and pH. Although certain differences were noted between the various types, it is not believed that a general soil survey would give significant data. A study of the soils with relation to the different lava flows from which they are derived might be of value. Because of the fact that decomposition is yet in the early stages, and the roots of plants penetrate through the shallow soil into the lava itself, differences in the lava and its decomposition products probably bear a close relationship to the nature and fertility of the soil.

COLLOIDAL SOIL INVESTIGATIONS

A study of the colloidal fraction of the Hawaiian laterite soils was made for the purpose of comparing it with that of Temperate Zone soils. The chief difference, other than that of the origin, between tropical volcanic and Temperate Zone soils is due to weathering processes which have been brought about under warm, humid conditions with excessive leachings. As a result, tropical volcanic soils are high in the sesquioxides and proportionately lower in silica and the basic oxides and contain larger amounts of organic matter. The presence of manganese and titanium in larger amounts than usual in the soils of many localities is also characteristic of Hawaiian soils. It is thought that these differences will manifest themselves in the properties of the colloidal phase, especially in the adsorbing and base-exchanging properties.

During field trips to the various districts of the four principal islands, samples of 82 different soils were collected in sufficient quantities for physical and chemical determinations. The selection of these soil samples was based on differences in physical and chemical characteristics such as soil reaction, percentage of organic matter, mechanical analysis, water-holding and hygroscopic properties, color, geographical location, and origin. As to agricultural or nonagricultural districts, 35 soil samples were taken from sugarcane fields, 8 from pineapple fields, 5 from coffee plantations (Kona), 2 from edible-canna fields, 7 from diversified agricultural areas, and 25 from districts where only native vegetation existed or where the land is barren. According to the different islands, 7 soil samples came from Oahu, 40 from Hawaii, 25 from Maui, and 10 from Kauai. In each instance data were collected as to the topographical, climatological, and agricultural nature of the district. In many instances, the subsoils were also included. The soils were card indexed, classified, and tabulated according to soil class, mechanical analysis, percentage of colloids, and chemical properties. On the basis of this preliminary analysis, 21 soils were selected for the main part of the investigation. These soils vary widely as regards elevation, origin, appearances, and physical characteristics. Thirteen are from agricultural and eight are from nonagricultural areas.

Considerable time was devoted to a study of the methods of dispersion of soils used by other investigators. It is essential in making mechanical analysis to obtain as complete a dispersion of the soil particles as possible. It is not always possible to achieve this by purely mechanical means, that is, by shaking or stirring. The addition of chemical compounds is usually necessary to aid deflocculation.

Tests were made of the efficiency of various mechanical dispersing devices including the end-over-end shaker, electrical stirrer, and rubbing by hand in mortar, as well as the use of certain chemicals such as sodium and potassium hydroxide, ammonia, and sodium carbonate. The results obtained indicate clearly that (1) the electrical stirring device is far superior to the other means; (2) the destruction of the soil organic matter by means of hydrogen peroxide is unnecessary even in soils containing 10 to 12 per cent organic matter; (3) the washing out of the calcium before dispersion is desirable with numerous soils, but that twentieth normal hydrochloric acid solution is just as efficient for this purpose as fifth normal acid; (4) hot digestion is not necessary; and (5) the addition of the hydroxyl ions for the stabilization of the charge on the colloidal particles is most efficiently done in the form of sodium hydroxide or sodium carbonate. In some soil samples almost complete dispersion was obtained without the aid of chemicals. The foregoing results are in close agreement with those obtained by other investigators.

After a dispersion as nearly perfect as possible was obtained, the colloids in suspension were separated by sedimentation according to Stokes's law, being supercentrifuged at the rate of 35,000 revolutions per minute when all the colloidal particles except the so-called ultra clay were retained in the centrifuge. This latter fraction passed through the centrifuge and was separated from the solution by filtration through a Pasteur-Chamberland filter, the ultra clay being retained on the surface of the filter. The colloids obtained in the dry state were purified by means of electrodialysis, the cell described by Mattson being used for the purpose.[4]

In the soils tested thus far the ultra-clay fraction was surprisingly large, in some instances comprising over 1 per cent of the soil. This was appreciably more than the amount obtained in a similar manner from mainland soils.

The adsorbing properties of the isolated colloids were studied. The amount of water vapor adsorbed over 3.3 per cent sulphuric acid was determined both for soils and colloids. This value is an index to the amount of colloidal matter present. The figures thus obtained both in soils and colloids followed the hygroscopic coefficient curve, but the percentage of colloid calculated from them did not agree well with figures obtained by the hydrometer and pipette methods. Bouyoucos's hydrometer method has been used rather extensively for comparative purposes, both in this and other projects, and experiments are under way to determine to what degree this method indicates the actual percentages of colloids in Hawaiian soils.

[4] MATTSON, S. ELECTRODIALYSIS OF THE COLLOIDAL SOIL MATERIAL AND THE EXCHANGEABLE BASES. Jour. Agr. Research 33: 553–567, illus. 1926.

MISCELLANEOUS NOTES

Specific-gravity determinations were made of the soils studied. These determinations were necessary in a study of the application of Stokes's law of settling particles, the velocity of settling being directly proportional to the specific gravity of the suspended particles. The specific gravity of the soils under examination was found to range from 2.19 to 3.36, depending on the amount of organic matter and sesquioxides present as determining factors. The highest (3.36) was a red clayey loam, while the lowest (2.19) was a black organic soil containing 18.5 per cent organic matter. Organic matter has a specific gravity of about 1.2 while that of the sesquioxides is about 5.3. The moisture equivalents as described by Briggs and McLane [5] was determined on a number of soils. These determinations were made on soils of the colloid study as well as on soils collected for other projects, such as the Kona coffee-land experiments. It is becoming customary to include this figure in soil-survey data as an index to water-holding capacity and to calculate the empirical "wilting coefficient" therefrom. The platted values run parallel with those of the hygroscopic coefficient and the moisture adsorbed in a saturated atmosphere.

An investigation was made to determine the causes of wilting of alfalfa in certain fields in the Koko Head region. Analyses of soil samples from these fields showed that they contained toxic accumulations of salt, presumably from the irrigation water, which contains as much as 75 grains of sodium chloride per gallon. The soil samples were examined for soil reaction (pH), soil colloids, total salts, sodium chloride, state of flocculation upon addition of water, the flocculating effect of various amounts of lime upon the puddled soils, and the presence or absence of soluble alkali carbonates.

REPORT OF THE AGRONOMY DIVISION

By H. L. Chung [6] and R. K. Lum

EDIBLE CANNA

The seven varieties of edible canna which were developed by the division three years ago have been grown continuously to determine their relative yield as compared with that of the original parent stock. In the last experiment these seedling varieties were grown on very sandy soils supplemented with commercial fertilizers. The results obtained indicated that soil which is very porous is not desirable for canna culture. Cultural tests were continued with the standard variety, No. 1039, from selected rootstocks grown on heavy soil. The yield obtained ranged from 18,798 to 24,891 pounds per acre.

CASSAVA

A cultural test with 14 varieties of cassava was begun December 3, 1926. After 28 months of growth the crop was harvested. Nine Blue Top plants made the heaviest yield, producing 413 pounds, or

[5] Briggs, L. J., and McLane, J. W. The moisture equivalents of soils. U. S. Dept. Agr., Bur. Soils Bul. 45, 23 p., illus. 1907.

[6] Transferred to extension service, University of Hawaii, June 30, 1929.

at the rate of 83 tons per acre. Other varieties produced from 8 to 49 tons per acre.

During the early part of 1927–28 the cassava plants bloomed profusely, and later produced seeds which matured and were planted. Observations on the seedling plants showed that many resembled the parent stock in color and pattern of leaves.

TARO

Both dry-land and wet-land varieties of taro were tested during the year. This test was begun primarily to determine the comparative yields of dry-land varieties selected from prolific stock; and of wet-land varieties grown on dry land, and to study the relative physical characteristics of the wet-land varieties.

Plantings were made of three varieties of Japanese dry-land taros taken from selected seed stock. On October 19, 1928, nine months after planting was done, the crop was harvested. Miyoko, No. 1886, gave the highest yield, producing at the rate of 20,473 pounds per acre, and was followed by Ahkado, No. 1883, with 18,738 pounds, and Trunoko, No. 1884, with 18,658 pounds. A similar planting of these varieties was made on September 18, 1928. On June 8, 1929, the crop was harvested. Miyoko again led with 13,310 pounds to the acre, and was followed by Trunoko with 11,374 pounds, and Ahkado with 11,132 pounds per acre.

In connection with this experiment, a cultural test with the three Japanese varieties was made to determine the value of corm and top for planting material. The results indicated that the top is the better planting material so far as yield is concerned.

Sixteen varieties of wet-land taro were tested. The four highest yields were produced by Oapu with 38,115 pounds per acre, Lehua and Kalalau each with 30,492 pounds, and Piko Uliuli with 28,858 pounds. Of the 10 Hawaiian dry-land varieties tested, Iaia gave the highest yield, 9,196 pounds, and was followed by Mana Eleele with 8,228 pounds, and Kai with 7,260 pounds.

In connection with the cultural tests of the dry-land and wet-land varieties of taro, a study was made of the proportions of top, corm, and fibrous roots of a taro plant as it was harvested. The average of all the dry-land varieties studied showed 31.7 per cent top, 54.7 per cent corm, and 14.8 per cent fibrous roots; and for the wet-land varieties, 52.2 per cent top, 34.1 per cent corm, and 13.6 per cent fibrous roots.

KUDZA

Kudzu (*Pueraria thunbergiana*) was cultivated for use as a forage and root crop. The planting yielded at the rate of 34 tons of roots per acre. Individual hills yielded 47 pounds of roots.

Kudzu is used primarily as an edible root crop by the orientals in Hawaii. However, in Hawaii and in Maui this legume finds a place as a forage crop on grazing lands.

GINGER

Two crops of Chinese and other gingers were grown with promising results.

SWEETPOTATOES

One hundred and thirty standard sweetpotato varieties and seedlings were grown during the year. Some of the seedlings produced seeds which matured. These are to be planted to permit a study of the variations in succeeding seedlings. Sweetpotato seeds from the above-mentioned source were distributed to various local agricultural institutions requesting them.

In cultural tests with other standard sweetpotato varieties, the yield ranged from 1,400 pounds to 9,095 pounds per acre, the latter yield being obtained from the Tantalus substation.

CORN

During the year new varieties of corn were tested, and an attempt was made to improve the size and shape of the Cuban Red corn kernels, and to segregate the white and the red cob characteristics in the yellow Guam corn.

A yellow dent corn from F. G. Krauss was grown at the station with very good results. The seed corn was obtained from the Parker ranch by Doctor Krauss, who requested that the variety be tried particularly under lowland conditions. The crop grown at the station is beginning to mature.

The local market demands a corn of golden color and small-sized kernels, and for this reason an attempt is being made to establish such a strain by selection. A yellow variety of Guam corn was developed by the station in 1920. Since then a variation has been noted in the color of the cobs, and efforts have been made to segregate two strains on the basis of cob color.

FORAGE GRASSES

During the past two years Mexican grass (*Exophorus unisetus*) has been vegetatively selected from heavy-stooling clumps. One outstanding planting included 16 rows, each of which occupied an area of 336 square feet, the plants being set 4 feet apart in the row. The yields of green feed obtained 67 days after the crop was planted were rather uniform, the lowest being 4,018.9 pounds per acre, and the highest 6,935.9 pounds, with an average of 5,397.8 pounds. Immediately after the harvest the area was treated with both organic and inorganic fertilizers. After 30 days the growth was harvested. The data obtained indicated that the areas receiving nitrate of soda, superphosphate (acid phosphate), and muriate of potash in combination yielded at the rate of 24,113 to 26,447 pounds per acre. This fertilizer experiment was continued until April 24, 1929, when the last harvest was made and yields were recorded.

Results of fertilizer tests with Napier grass (*Pennisetum purpureum*) and Merker grass (*P. merkeri*) indicated that the plats receiving nitrate of soda at the rate of 450 pounds per acre gave the best results.

Napier-grass cuttings are frequently held until the field has been prepared for planting. An experiment was made to determine the length of life of Napier grass. Propagating material which was piled in a heap and exposed to the weather was found to make 100 per cent growth 29 days after cutting. After the twenty-ninth day,

however, deterioration was rapid. Napier-cane cuttings when piled in a heap in a shed showed a 60 per cent growth 65 days after cutting. However, no growth was obtained from a lot similarly protected from the sun 74 days after cutting.

Kikuyu grass (*P. clandestinum*) is very promising. The plant establishes itself readily on new ground by means of its runners, and attains an average height of 3 feet. The division was unable to comply with all the requests from stockmen and farmers for this grass to establish new pasture areas.

Plats demonstrating range grasses were again maintained for the benefit of those who are interested in them.

ORIENTAL-VEGETABLE CULTURE

Studies of oriental-vegetable culture were confined to aquatic species, including the lotus root (*Nelumbium nelumbo*), arrowhead (*Sagittaria sagittifolia*), and Jesuits' nut (*Trapa natans*).

GREEN-MANURING CROPS

The hyacinth-bean (*Dolichos lablab*) and the Mauritius bean were cultivated during the year to determine their adaptability as green-manuring crops. Both made heavy vegetative growth. The *D. lablab* produced 18 tons of green matter per acre four months after planting and the Mauritius beans yielded a similar amount for the same period.

RICE LANDS

Largely on account of the inroads made by the rice borer (*Chilo simplex*) during the past two years, more than 80 per cent of the rice-growing lands are now being abandoned. Landowners and lessees are anxious to know how these rice lands may best be used. In some places where the soil is loose, vegetables and flowers may be grown to advantage provided that the cost of transporting them to market is not too high. This land may be leased for such purposes at an attractive rental. On the heavy-soil type the growing of soiling crops may be possible, or grasses for grazing purposes may be planted. Those who are horticulturally inclined may find it to their advantage to furrow the land deeply and then establish a litchi-fruit orchard on the ridges. The furrows would make it possible to keep water on both sides of the ridge so that an abundance of moisture would be available for the trees at all times. This method of planting is similar to that used in the litchi orchards of southern China.

LETTUCE BREEDING

The agronomy division has been endeavoring for five years to develop a strain of lettuce that will head satisfactorily in the Hawaiian Islands. It has been necessary in the past to grow the head-lettuce plants at an altitude of 1,000 feet or more. Heat seems to stimulate the growth of the internodes and thus inhibits the tendency to head. The experiment started with 14 standard varieties to determine their reactions to local environment. The seven most promising varieties were used in hybridization work which is still under way in an attempt to fix a desirable type of solid-headed lettuce.

POULTRY

During the time that could be spared from agronomic work the agronomist again assisted poultrymen with problems in connection with the poultry industry. Poultry diseases and methods of controlling them received much attention. Articles of interest to poultrymen were submitted to the local press until December, 1928. In October and again during the early part of December the agronomist assisted with the Kauai poultry and pigeon show.

REPORT OF THE HALEAKALA SUBSTATION

By H. F. Willey

At the Haleakala substation 30 rods of new fence were constructed and 56 rods of old fence rebuilt. Most of the fence posts were obtained from eucalyptus trees which were planted at the substation in 1922. Clearing of the gulch land was continued for additional plantings of coffee, fruit, and nut trees, grapes, and berries. Three-hundred and fifty trees had already been set out. Approximately 188 varieties of 60 different species of crops were under test, including pigeon peas, edible canna, cassava, dry-land taro, sweetpotatoes, forage and pasture grasses, and many varieties of peppers, tomatoes, grapes, watermelons, muskmelons, and other fruits and vegetables. Distribution of planting material of all the improved strains under test was continued as in past years. Distributions were made of more than 100 pounds of improved field seeds, 185 pounds of edible-canna tubers, 2,000 sweetpotato plants, 500 strawberry plants, 300 pounds of taro tubers, and twelve 1½-ton truck loads of Napier and Merker grass cuttings. The substation has 1 registered Holstein bull, 2 mules, 3 cows, 1 heifer, 3 calves, 1 hog, 1 saddle pony, 1 filly, about 40 chickens, and nearly a dozen rabbits.

Experiments were made with pineapples to determine the effect on yield of using different cover and green-manure crops with and without fertilizer. The average weight of the pineapples was 3.71 pounds following lupines, 3.37 pounds following edible canna, 3.48 pounds following jack beans, and 3.59 pounds following sweetpotatoes. The plat receiving sulphate of ammonia at the rate of 250 pounds per acre produced fruits averaging 3.72 pounds, whereas the unfertilized plats produced fruits averaging 3.02 pounds. Other experimental plantings of pineapples totaling several thousand plants have been made, but none of the crops have as yet matured. There are at present 10,626 pineapple plants growing at the substation and 1,400 aditional plants have been put out with a private cooperator at an elevation of approximately 3,300 feet. (Fig. 8.)

The superintendent continued to give considerable attention to agricultural extension work. In this connection he traveled about 3,400 miles between July 1 and December 31, 1928. At this time he was placed on part-time basis with the newly reorganized agricultural extension service of the University of Hawaii. He also made numerous trips to various parts of the island to assist homesteaders and others in the culture of diversified crops and gave advice and demonstrations in poultry culling and in artificial incubation. He also gave demonstrations in spraying various crops re-

quiring such treatment. In connection with the 4–H club work, 11 boys' and girls' 4–H clubs were organized with a total membership of 116. (Fig. 9.) The farm club work included gardening clubs,

FIGURE 8.—Cooperative experiment with pineapples, Maui (3,300 feet elevation). Plants mulched with paper to conserve heat and moisture. Altitude is about 2,000 feet above the customary maximum for pin apple production in the Hawaiian Islands

poultry clubs, pigeon clubs, rabbit clubs, and pig clubs. During the year the superintendent took charge of the first boys' and girls' 4–H club camp ever held in the Territory of Hawaii. This camp was held at the Haleakala substation May 24 and 25, 1929. Twelve of the

FIGURE 9.—Peppy Girls' 4–H Sewing Club. Director W. A. Lloyd and Club Leader Mrs. E. A. Willey, standing. Haleakala substation

14 clubs operating on Maui were represented at the camp. Koichi Ito of Hamakuapoko, Maui, a club member, was sent as a delegate to the National Boys' and Girls' 4–H Club camp at Washington, D. C., during the summer of 1929.

Commencing January 1, 1929, the superintendent was placed on half-time basis with the agricultural extension division of the University of Hawaii, cooperating with the United States Department of Agriculture. The station, however, continued to finance a portion of the extension activities of the superintendent until June 30, 1929, at which time he again assumed full-time activities there.

REPORT OF EXTENSION AND DEMONSTRATION WORK

By R. A. Goff

The extension agent served with the extension division of the station from July 1, 1928, to December 31, 1929, when he was transferred on full-time basis to the extension division of the University of Hawaii, cooperating with the United States Department of Agriculture. During his six months with the station he continued to act as general county agent for the island of Hawaii and to visit farmers for the purpose of advising them regarding crop rotations, feeding problems, and orchard planning and culture. He also spent considerable time in arranging for range-grass demonstrations. These were based on observations made in previous years at the cooperative grass plantings on the Parker ranch and elsewhere. Specimens of the more important grasses were obtained for botanical study and chemical analysis.

REPORT OF BOYS' AND GIRLS' CLUB WORK

By Mabel Greene

Incident to the changes in the administration and organization of the agricultural extension work, the club activities were confined to the rural districts of the island of Oahu. The work was enlarged to include women's club work as well as girls' club work. The boys' club work was directed by a representative of the University of Hawaii. The women's and girls' club work included clothing and food preservation and utilization. Attention was also given to home improvement, and instruction and assistance were given in making such house furnishings as curtains, table covers, pillowcases, sheets, bedspreads, towels, and children's clothes. An attempt was made during the first six months of the year to correlate this work as closely as possible with the new lines of extension activities at the University of Hawaii in cooperation with the United States Department of Agriculture. On January 1, 1929, the boys' and girls' club work was transferred to the University of Hawaii.

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